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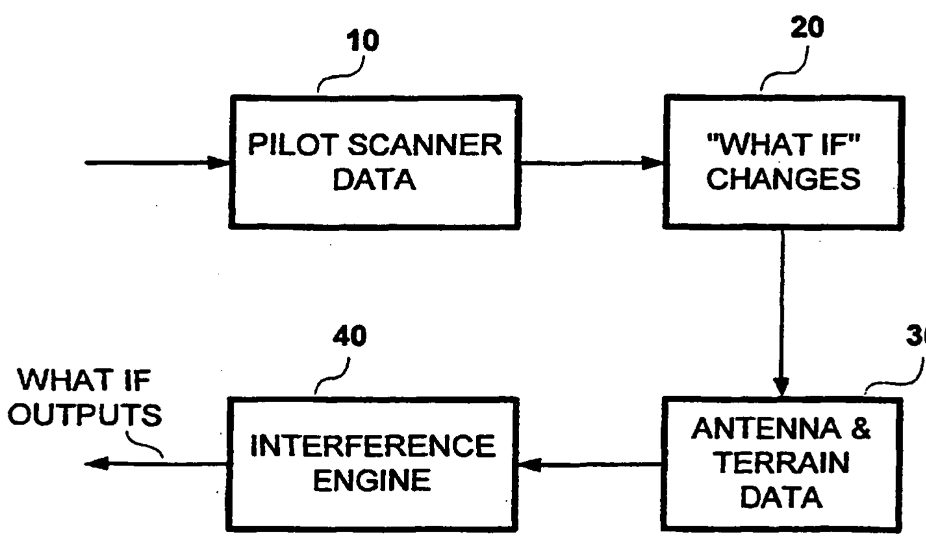

(57) Abstract: A wireless network can be easily optimized utilizing processes according to the present invention. A simulation environment allows a network engineer to vary parameters (e.g., antenna height, tilt, and power) of a virtual model of the wireless network and observe how the changes affect coverage. Algorithms also enable hand off timing parameters for sectors in a wireless network to be optimized. One algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended values for window size paramaters (code division systems) or timing advance parameters (time division systems). Another algorithm analyzes measured data regarding network coverage to arrive at a report containing recommended neighbour list for each sector in the network.

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Title: WIRELESS TELEPHONE NETWORK OPTIMIZATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to the art of wireless telephone networks. More particularly, the present invention is directed to optimizing parameters of radio base stations in a wireless telephone network.

2. Background Information

Cellular and PCS telephone services have enjoyed explosive growth over the last ten years. There is no reason to believe that this growth will not continue for some time. This continued growth creates a great demand for the infrastructure that supports these services. As more and more people begin to use wireless telephones, more and more fixed location base stations must be installed across the landscape to handle the rising demand for wireless traffic.

Each wireless telephone base station has a plurality of transceivers, each connected to a respective antenna. The electromagnetic radiation pattern of each of these antennas defines the coverage area of a "sector." Each sector in the wireless network has some degree of overlap with one or more nearby sectors, and in the aggregate, the coverage areas of all the sectors in the network define coverage area of the network as a whole.

One difficulty in establishing a network of base stations is that the aggregate coverage provided by the sectors is not perfect. It may have weak spots, or self-interference spots, where wireless telephony functions at a substandard level or it may even have dead spots where no wireless calls can function at all. Such problems can be rectified by optimizing the sectors to attempt to cover the weak and/or dead spots in wireless coverage. Coverage optimization may be accomplished by varying a number of parameters for each sector. One parameter to vary is the azimuth angle at which the antenna for the sector is pointed. Other parameters to vary are the antenna height (moving the antenna higher or lower on its tower, host building, or other supporting structure), the angle of tilt of the antenna (useful in uneven terrain locations), and the amount of power radiated by the antenna. Additionally, the option is also available to substitute a different

type of antenna (different model or different manufacturer entirely) in order to obtain better coverage results.

This optimization process is laborious and time consuming. Each time a network engineer wants to change four of the five above-identified parameters of a sector (azimuth, height, tilt, antenna type), someone has to climb up a tower (or other support structure) and physically make an adjustment to the antenna. Only power changes can be made without a need to get at the antenna. Once a parameter has been varied, a fresh set of signal strength measurements must be made by physically driving around the relevant terrain with a measurement device to map out how the parameter change has affected coverage. After analyzing the measurements, another parameter (perhaps for a different sector) can then be varied. This iterative process of vary-measure-vary-measure is repeated over and over again until an optimum result is obtained. It takes a long time and relies upon highly skilled workers to accomplish.

Thus, what is needed is a labor-saving and time-efficient way to develop optimum coverage-related parameters for sectors of a wireless network.

A wireless telephone often communicates via a number of sectors in succession in the course of a single telephone call via a process called hand-off. In simple terms, one sector will transfer to a neighboring sector the responsibility for handling the wireless telephone call. A hand off may be necessitated because the wireless telephone unit is portable and has moved out of the effective range of the sector that had been heretofore handling the call, or it may be necessitated due to high demand for the limited number of channels that the sector can provide. This is (ideally) done in a seamless manner such that the user of the telephone never notices any discontinuity in service.

In order for call hand offs between sectors to be performed effectively, a number of parameters of the hardware supporting each sector need to be optimized. One parameter is called a "neighbor list." Each sector has a neighbor list, which is a ranked listing of neighboring sectors to which hand offs may most appropriately be made. The ranking of members in a neighbor list is an important factor in enabling effective hand offs. However, prior art practice is for a network engineer to simply make an educated guess as to which neighboring sectors should be included as members of the neighbor list of a given sector, as well as how to rank the members of the list by importance. Prior art

practice does not include a rigorous analysis of how members of a neighbor list should be ranked, or even which neighboring sectors should be included as members of the list.

Another parameter relevant to hand off effectiveness in CDMA wireless networks is "window size." Window size is a parameter that is set for each sector uniquely. This parameter tells a mobile wireless telephone unit how wide a "window" of code space (in chips) the mobile unit should search through in order to attempt to synchronize with the PN (pseudo noise) sequence of a given sector. As a general rule, it is desirable to set the window size parameter to be the smallest size that will give an acceptable rate of capture of the PN sequence of the sector.

The prior art provides no satisfactory device or process for optimizing choices of window size for the sectors in a network. As with coverage optimization, a network engineer must program the window size parameter at each sector based on his or her best guess as to what should be an optimum value.

A related concept in time division type wireless networks (e.g., GSM, TDMA, iDEN) is the "timing advance" parameter. Timing advance is an analogous concept to the window size parameter of CDMA networks, but is directed to finding an appropriate time slot rather than to code synchronization. The prior art does not provide a suitable way to optimize timing advance, either, leaving network engineers to guess their way to an optimum solution. Such a haphazard optimization technique is not an efficient use of the time of highly skilled workers.

Thus, what is needed is an effective way to optimize hand off timing parameters for sectors in a wireless network.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a labor-saving and time-efficient way to develop optimum coverage-related parameters for sectors of a wireless network.

To address the need for a way to develop optimum coverage-related parameters for sectors of a wireless network, the present invention provides a simulation environment. This simulation environment allows a network engineer to vary parameters of a virtual model of the wireless network and observe how the changes affect coverage.

It is another object of the present invention to provide algorithms to optimize hand off timing parameters for sectors in a wireless network.

To address the need for a way to optimize hand off timing parameters for sectors in a wireless network, the present invention provides an optimization algorithm. The optimization algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended values for window size parameters (code division systems) or timing advance parameters (time division systems). The optimization algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended neighbor lists for each sector.

Some of the above objects are obtained by a process of modeling signal strength coverage of a wireless network based on empirical coverage measurements for the network over a region of interest, based on user inputs, and based on terrain data in the region of interest, the network having plural base station antennas. The process includes mapping the empirical coverage measurements onto the terrain data to provide an initial coverage model, and receiving from a user an input for change of a parameter of one of the antennas. The process also includes generating outputs of signal strength at points on the terrain that are affected by the parameter change, and modifying the initial coverage model based on the generated outputs of signal strength to provide a hypothetical coverage model.

Some of the above objects are also obtained by a process of generating a neighbor list for a sector-of-interest in a wireless network based on empirical measurements of signal to noise ratio. The process includes calculating a weight for every pair wise combination of the sector-of-interest other network sectors between which a predetermined threshold signal level criteria, T_ADD, is met. The process also includes ordering the calculated weights from largest to smallest, and listing the sectors that meet the T_ADD criteria with respect to the sector-of-interest in rank order corresponding to the ordered calculated weights.

Some of the above objects are also obtained by a process of selecting a value of window size for a sector-of-interest in a code division multiple access wireless network. The process includes selecting the earliest arriving multipath signal of all sectors that meet the threshold criteria Ec/Io > T_ADD, wherein T_ADD is a predetermined threshold signal level, and selecting a pair of sectors, ToSector and FromSector, that meet the threshold criteria Ec/Io > T_ADD. The process also includes setting a window size of

FromSector = chip delay of ToSector - chip delay of the earliest arriving multipath sector, evaluating whether the window size of FromSector > maximum window size, and in the event that the window size of FromSector is greater that the maximum window size, then set maximum FromSector window size = the window size of FromSector.

Some of the above objects are also obtained by a process of generating a value of timing advance for a sector-of-interest in a time division-type wireless network. The process includes selecting a sector, FromSector, with a sufficient Received Signal Strength Indication (RSSI) to serve a call, calculating the distance to FromSector, and setting timing advance of FromSector = one half the distance to FromSector. The process also includes evaluating whether FromSector's timing advance > maximum timing advance, and in the event that FromSector's timing advance is greater than the maximum timing advance, then set maximum FromSector timing advance = FromSector timing advance.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a high-level flow chart for performing simulation according to an embodiment of the present invention.

Fig. 2 illustrates an antenna dialog box according to an embodiment of the present invention.

Fig. 3 illustrates a user interface for inputting proposed changes to the network's parameters and displaying simulation results according to an embodiment of the present invention..

Fig. 4 illustrates a detail view of the sector select window of **Fig. 3**.

Fig. 5 illustrates a map output display according to an embodiment of the present invention.

Fig. 6 illustrates a graph output display according to an embodiment of the present invention.

Fig. 7 illustrates an optimized neighbor list generated according to one aspect of the present invention.

Fig. 8 illustrates a flowchart for an algorithm to ascertain an appropriate window size for a sector of a CDMA wireless network according to another aspect of the present invention.

Fig. 9 illustrates a flowchart for an algorithm to ascertain an appropriate timing advance for a sector of a time division-type wireless network according to yet another aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Several types of input information are initially gathered together to create a virtual environment for purposes of simulation of a wireless network. Once the baseline representing the *status quo* is established, a user is able to perform simulations by varying one or more parameters from those that exist in reality. The varied parameters have many affects on performance of the system, and these effects are modeled by the present invention.

Referring to **Fig. 1** a high-level flow chart illustrates how simulation is done according to the present invention. Data gathered by a pilot scanner (gathered over days or even weeks of "drive" tests) is used to provide a comprehensive mapping **10** of signal strengths of the sectors of a wireless network in a given region. A user then proposes "what if" changes **20** to the parameters of the network. The pilot scanner data and the proposed "what if" changes are utilized along with data pertaining to antennas used (or that may be used) in the network and three dimensional cartographic data **30** as inputs to an interference engine **40**. The interference engine **40** is an algorithm that takes the above-described inputs and generates "what if" outputs of signal strength at points on the terrain that are affected by the proposed "what if" changes. In addition to measured RF data (from drive tests), antenna data, and terrain data, MSC information may also be input.

Referring to **Fig. 2**, an antenna dialog box is illustrated. Via the antenna dialog box, antenna data is made available for a user to select as input data. A particular antenna may be selected according to manufacturer and model number **60**. Textual information is displayed **80** for the user's consideration, along with graphical displays of an antenna's horizontal gain **50** and vertical gain **70**.

Referring to **Fig. 3**, a user interface for inputting proposed changes to the network's parameters is illustrated. A "before" plot of E_C/I_0 versus time **110** is displayed adjacent an "after" plot of E_C/I_0 versus time **120**. A sector select window for varying parameters of selected sectors **130** is shown along side the signal versus time plots **110**, **120**. The illustrated example shows that sector number 405-2 has been selected and that

one parameter, antenna downtilt, has been changed from 6 degrees to 8 degrees. The signal strength plot for sector 405-2 is highlighted in red in both plots **110, 120**. It is clear from inspection of the after plot **120** to the before plot **110** that the proposed antenna downtilt change would have a markedly bad affect on the performance of the sector.

Referring to **Fig. 4**, a detail of the sector select window **130** is illustrated to provide a detailed view of how various parameters of a selected sector can be varied for simulation. A selection button **405** provides for a user to select any sector in the wireless network for proposed parameter changes.

The antenna azimuth parameter may be changed via the azimuth slide control **425**, the actual azimuth value being displayed in brackets **410** and the proposed value **415** being displayed adjacent the azimuth slide control **425**. The antenna height parameter may be changed via the height slide control **440**, the actual height value (shown in meters) being displayed in brackets **430** and the proposed value **435** being displayed adjacent the height slide control **440**. The antenna downtilt parameter may be changed via the downtilt slide control **455**, the actual downtilt value being displayed in brackets **445** and the proposed value **450** being displayed adjacent the downtilt slide control **455**.

The sector transmission power parameter may be changed via the power delta (i.e., change in power) slide control **465**, the original power delta value (zero) is displayed in brackets **460** and the proposed power delta value **470** is displayed adjacent the power delta slide control **465**. The user is also free to change the type of antenna being used in the simulation. The actual *status quo* antenna type is displayed in brackets **475** and the selected antenna type is displayed **480** under the "antenna" label. Selections of antenna types are made via the antenna dialog box shown in Fig. 2.

Simulation is performed by numerical calculations performed by an interference engine. The simulation algorithm receives input information in the following form:

- The list of sectors the user wants to change. The simulation needs the old and new power/height/downtilt/azimuth for every sector changed.
- The following measurements at each location where the user wants to simulate the change:
  - Ec_iRc — pilot channel power for sector i (units dBm)
  - $(E_c/I_0)_i$ — pilot channel signal-to-noise ratio for sector i (units dB)

- I_oW — total received power at this location (units dBm)

The input measurements are typically received in units of dB or dBm, which are nonlinear (logarithmic) units. As most of the calculations disclosed are in linear units, a conversion from logarithmic to linear units would be necessary.

Once the input data has been properly initialized, the following process steps are performed:

1) Use pilot channel powers to find X, where X is defined as:

$$X = I_oW / \mathrm{sum}(Ec_iRc)$$

2) For each sector whose power or antenna has changed, calculate the new Ec_iRc, which is denoted as Ec_iRc', after antenna changes:

$$\begin{gathered} Ec_iRc' = Ec_iRc - oldAntennaGain\ at\ LOS\ path\ from\ antenna\ to\ this\ location \\ + newAntennaGain\ at\ LOS\ path\ from\ antenna\ to\ this\ location \\ - oldPower\ for\ this\ sector \\ + newPower\ for\ this\ sector \end{gathered}$$

[NOTE: This calculation is written for dB units instead of linear units]

3) Calculate the new total received power, I_oW', at this location after antenna changes:

$$I_oW' = X \cdot \mathrm{sum}(Ec_iRc')$$

4) Find the new E_c/I_o value, for a sector i, at this location after antenna changes:

$$(E_c/I_o)_i' = Ec_iRc' / I_oW'$$

5) Perform this for every location that contains measurements from changed sectors.

Once the algorithm has been performed for all changed sectors, the resulting simulation data, Ec_iRc', $(E_c/I_o)_i'$ and I_oW', needs to be converted back into logarithmic units (dB or dBm units). These are the results of the simulation that the user will see. The above formulas are preferred simplifications based on a rigorous mathematical derivation.

Simulation outputs are provided as signal strength maps, either two dimensional or virtual reality, as tables of numerical data, and as charts. Referring to **Fig. 5**, an example, according to an embodiment of the present invention, of a two-dimensional map simulation output is illustrated. Referring to **Fig. 6**, an example, according to an embodiment of the present invention, of a graph output is illustrated.

The present invention also performs automated optimization of parameters affecting hand off, and generates reports of such automated optimization results.

One parameter that is automatically optimized according to the present invention is Window Size in a CDMA system. As a general rule, it is desirable to set the window size parameter to be the smallest size that will give an acceptable rate of capture of the PN sequence of the sector. Since the prior art provides no satisfactory device or process for optimizing choices of window size for the sectors in a network, network engineers have no choice but to program the window size parameter at each sector based on a best guess as to what may be an optimum value.

The present invention provides an algorithm that predicts optimum window size based on empirical measurements. The input parameters to the algorithm are E_C/I_0, pilot channel SNR for a given sector, measured delay time τ from the base location to a given measuring location, and the location information itself. Another factor that affects the algorithm is an assumption that is made as to which particular sector in the network provides the reference time for the hypothetical mobile unit to be handed off.

Referring to **Fig. 8**, a flowchart for an algorithm to ascertain an appropriate window size for a subject sector of a CDMA wireless network is illustrated. The algorithm is applied to empirical drive test data. Multipath signals of all sectors are evaluated to see if they meet the threshold criteria Ec/Io > T_ADD, and then the earliest arriving is selected **810** therefrom. A pair of sectors, ToSector and FromSector, are selected **820**, which meet the threshold criteria Ec/Io > T_ADD. The window size of the subject sector (i.e., FromSector's window size) is set **830** to a value that is equal to ToSector's chip delay, less the chip delay of the earliest arriving multipath sector. An evaluation is then made **840** as to whether FromSector's window size is greater than the maximum window size of the subject sector. If it is, then the maximum FromSector window size is set **850** to equal to the window size for the subject sector. If it is not, then no action is taken.

In either case, an evaluation is then made **860** as to whether this is the last sector measured at a given location. If not, then the algorithm loops back to the step of selecting **820** a pair of sectors, ToSector and FromSector. If so, then the algorithm proceeds on to the next measurement location **870** and continues to repeat the algorithm as described above. The algorithm is exhausted **880** when the last measurement location has been exhausted.

A related concept in time division type wireless networks (e.g., GSM, TDMA, iDEN) is the "timing advance" parameter. Timing advance is an analogous concept to the window size parameter of CDMA networks, but is directed to finding an appropriate sector signal transmission timing advance rather than to code synchronization. Calculation of optimum timing advance is performed in an analogous manner as to window size.

Referring to **Fig. 9**, a flowchart for an algorithm to ascertain an appropriate timing advance for a sector of a time division type wireless network is illustrated. The algorithm is applied to empirical drive test data. A sector, FromSector is selected **910,** with a sufficient Received Signal Strength Indication (RSSI) to serve a call. The distance to FromSector is then calculated **920**. The timing advance of the subject sector (i.e., FromSector's timing advance) is set **930** to a value that is equal to be half of the calculated distance. An evaluation is then made **940** as to whether FromSector's timing advance is greater than the maximum timing advance of the subject sector. If it is, then the maximum FromSector timing advance is set **950** to equal to the timing advance for the subject sector. If it is not, then no action is taken.

In either case, an evaluation is then made **960** as to whether this is the last sector measured at a given location. If not, then the algorithm loops back to the step of selecting **920** a sector of sufficient RSSI. If so, then the algorithm proceeds on to the next measurement location **970** and continues to repeat the algorithm as described above. The algorithm is exhausted **980** when the last measurement location has been exhausted.

Each sector in a wireless network has a neighbor list. Conventionally, the neighbor list was input by a network engineer making a judgement call as to what looked like the best prioritization of which neighboring sectors were most relevant to the subject sector for purposes of making hand offs of calls. For the wireless network to operate effectively, it is important that the prioritization of members of the neighbor list for each sector be accurate.

The primary factor in determining ranking of neighbor list members is a quantity called "weight." Weight is calculated, with respect to two neighbor sectors "a" and "b", as follows:

$$\text{weight}_{a\rightarrow b} = \sum_{i=1}^{n} 10\text{^}\{[(E_C/I_0(a,i) - T\_ADD) + (E_C/I_0(b,i) - T\_ADD)]/10\}$$

In this equation E_C is the energy per chip in the relevant pilot channel (a or b in this example), I_0 is the total noise power spectral density, E_C/I_0 is the signal-to-noise ratio of each sector at each location, and T_ADD is a predetermined threshold signal level. The value of n represents the number of locations over which summation is to occur.

This weight calculation is calculated for every pair wise combination of sectors between which the T_ADD threshold criteria is met. The input information for this formula is the empirical measurements of E_C/I_0.

Referring to **Fig. 7**, a table is shown that comprises an output report according to the automatic optimization aspect of the present invention. The Sector Name column lists, in descending rank order, the ten sectors that make up the Neighbor List for sector number 161-3. The SRCH_WIN_N column lists the optimized search window sizes for the sectors on the Neighbor List.

Additionally, the present invention generates a Neighbor Discrepancy List, which is a comparison of the Neighbor List before optimization and the Neighbor List after optimization.

Although the present invention has been described in terms of preferred embodiments, various modifications and variations may be made without departing from the scope of the invention, as will be understood by those of skill in the art. The present invention is limited only by the appended claims.

WHAT IS CLAIMED IS:

1. A process of modeling signal strength coverage of a wireless network based on empirical coverage measurements for the network over a region of interest, based on user inputs, and based on terrain data in the region of interest, the network having plural base station antennas, the process comprising:

mapping the empirical coverage measurements onto the terrain data to provide an initial coverage model;

receiving from a user an input for change of a parameter of one of the antennas;

generating outputs of signal strength at points on the terrain that are affected by the parameter change; and

modifying the initial coverage model based on the generated outputs of signal strength to provide a hypothetical coverage model.

2. The process of claim 1, wherein the parameter is chosen from the group consisting of: antenna height, antenna tilt angle, antenna type, antenna azimuth, and transmitted signal power at the antenna.

3. The process of claim 1, further comprising:

providing a visual representation of signal strength coverage according to the initial coverage model.

4. The process of claim 1, further comprising:

providing a visual representation of signal strength coverage according to the hypothetical coverage model.

5. The process of claim 1, further comprising:

providing a comparative visual representation of signal strength coverage according to superposition of the initial coverage model with the hypothetical coverage model.

6. A process of generating a neighbor list for a sector-of-interest in a wireless network based on empirical measurements of signal to noise ratio, the process comprising:

calculating a weight for every pair wise combination of the sector-of-interest other network sectors between which a predetermined threshold signal level criteria, T_ADD, is met;

ordering the calculated weights from largest to smallest; and

listing the sectors that meet the T_ADD criteria with respect to the sector-of-interest in rank order corresponding to the ordered calculated weights.

7. The process of claim 6, wherein weight is calculated, with respect to two neighbor sectors a and b, as follows:

$$\text{weight}_{a\rightarrow b} = \sum_{i=1}^{n} 10\hat{}\{[(E_C/I_0(a,i) - T\_ADD) + (E_C/I_0(b,i) - T\_ADD)]/10\}$$

wherein E_C/I_0 is the signal-to-noise ratio of each sector at each location, and the value of n represents the number of locations over which summation is to occur.

8. A process of selecting a value of window size for a sector-of-interest in a code division multiple access wireless network, the process comprising:

select the earliest arriving multipath signal of all sectors that meet the threshold criteria Ec/Io > T_ADD, wherein T_ADD is a predetermined threshold signal level;

select a pair of sectors, ToSector and FromSector, that meet the threshold criteria Ec/Io > T_ADD;

set a window size of FromSector = chip delay of ToSector - chip delay of the earliest arriving multipath sector;

evaluate whether the window size of FromSector > maximum window size; and

in the event that the window size of FromSector is greater that the maximum window size, then set maximum FromSector window size = the window size of FromSector.

9. A process of generating a value of timing advance for a sector-of-interest in a time division-type wireless network, the process comprising:

select a sector, FromSector, with a sufficient Received Signal Strength Indication (RSSI) to serve a call;

calculate the distance to FromSector;

set timing advance of FromSector = one half the distance to FromSector;

evaluate whether FromSector's timing advance > maximum timing advance; and

in the event that FromSector's timing advance is greater than the maximum timing advance, then set maximum FromSector timing advance = FromSector timing advance.

10. A computer program product for enabling a computer to model signal strength coverage of a wireless network based on empirical coverage measurements for the network over a region of interest, based on user inputs, and based on terrain data in the region of interest, the network having plural base station antennas, the computer program product comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium embodying the software instructions;

the predetermined operations comprising:

mapping the empirical coverage measurements onto the terrain data to provide an initial coverage model;

receiving from a user an input for change of a parameter of one of the antennas;

generating outputs of signal strength at points on the terrain that are affected by the parameter change; and

modifying the initial coverage model based on the generated outputs of signal strength to provide a hypothetical coverage model.

11. A computer program product for enabling a computer to generate a neighbor list for a sector-of-interest in a wireless network based on empirical measurements of signal to noise ratio, the computer program product comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium embodying the software instructions;

the predetermined operations comprising:

calculating a weight for every pair wise combination of the sector-of-interest other network sectors between which a predetermined threshold signal level criteria, T_ADD, is met;

ordering the calculated weights from largest to smallest; and

listing the sectors that meet the T_ADD criteria with respect to the sector-of-interest in rank order corresponding to the ordered calculated weights.

12. A computer program product for enabling a computer to select a value of window size for a sector-of-interest in a code division multiple access wireless network, the computer program product comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium embodying the software instructions;

the predetermined operations comprising:

select the earliest arriving multipath signal of all sectors that meet the threshold criteria Ec/Io > T_ADD, wherein T_ADD is a predetermined threshold signal level;

select a pair of sectors, ToSector and FromSector, that meet the threshold criteria Ec/Io > T_ADD;

set a window size of FromSector = chip delay of ToSector - chip delay of the earliest arriving multipath sector;

evaluate whether the window size of FromSector > maximum window size; and

in the event that the window size of FromSector is greater that the maximum window size, then set maximum FromSector window size = the window size of FromSector.

13. A computer program product for enabling a computer to generate a value of timing advance for a sector-of-interest in a time division-type wireless network, the computer program product comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium embodying the software instructions;

the predetermined operations comprising:

select a sector, FromSector, with a sufficient Received Signal Strength Indication (RSSI) to serve a call;

calculate the distance to FromSector;

set timing advance of FromSector = one half the distance to FromSector;

evaluate whether FromSector's timing advance > maximum timing advance; and

in the event that FromSector's timing advance is greater than the maximum timing advance, then set maximum FromSector timing advance = FromSector timing advance.

14. A computer system adapted to model signal strength coverage of a wireless network based on empirical coverage measurements for the network over a region of interest, based on user inputs, and based on terrain data in the region of interest, the network having plural base station antennas, comprising:

a processor, and

a memory including software instructions adapted to enable the computer system to perform operations comprising:

mapping the empirical coverage measurements onto the terrain data to provide an initial coverage model;

receiving from a user an input for change of a parameter of one of the antennas;

generating outputs of signal strength at points on the terrain that are affected by the parameter change; and

modifying the initial coverage model based on the generated outputs of signal strength to provide a hypothetical coverage model.

15. A computer system adapted to generate a neighbor list for a sector-of-interest in a wireless network based on empirical measurements of signal to noise ratio, comprising:

a processor, and

a memory including software instructions adapted to enable the computer system to perform operations comprising:

calculating a weight for every pair wise combination of the sector-of-interest other network sectors between which a predetermined threshold signal level criteria, T_ADD, is met;

ordering the calculated weights from largest to smallest; and

listing the sectors that meet the T_ADD criteria with respect to the sector-of-interest in rank order corresponding to the ordered calculated weights.

16. A computer system adapted to select a value of window size for a sector-of-interest in a code division multiple access wireless network, comprising:

a processor, and

a memory including software instructions adapted to enable the computer system to perform operations comprising:

select the earliest arriving multipath signal of all sectors that meet the threshold criteria Ec/Io > T_ADD, wherein T_ADD is a predetermined threshold signal level;

select a pair of sectors, ToSector and FromSector, that meet the threshold criteria Ec/Io > T_ADD;

set a window size of FromSector = chip delay of ToSector - chip delay of the earliest arriving multipath sector;

evaluate whether the window size of FromSector > maximum window size; and

in the event that the window size of FromSector is greater that the maximum window size, then set maximum FromSector window size = the window size of FromSector.

17. A computer system adapted to generate a value of timing advance for a sector-of-interest in a time division-type wireless network, comprising:

a processor, and

a memory including software instructions adapted to enable the computer system to perform operations comprising:

select a sector, FromSector, with a sufficient Received Signal Strength Indication (RSSI) to serve a call;

calculate the distance to FromSector;

set timing advance of FromSector = one half the distance to FromSector;

evaluate whether FromSector's timing advance > maximum timing advance; and

in the event that FromSector's timing advance is greater than the maximum timing advance, then set maximum FromSector timing advance = FromSector timing advance.

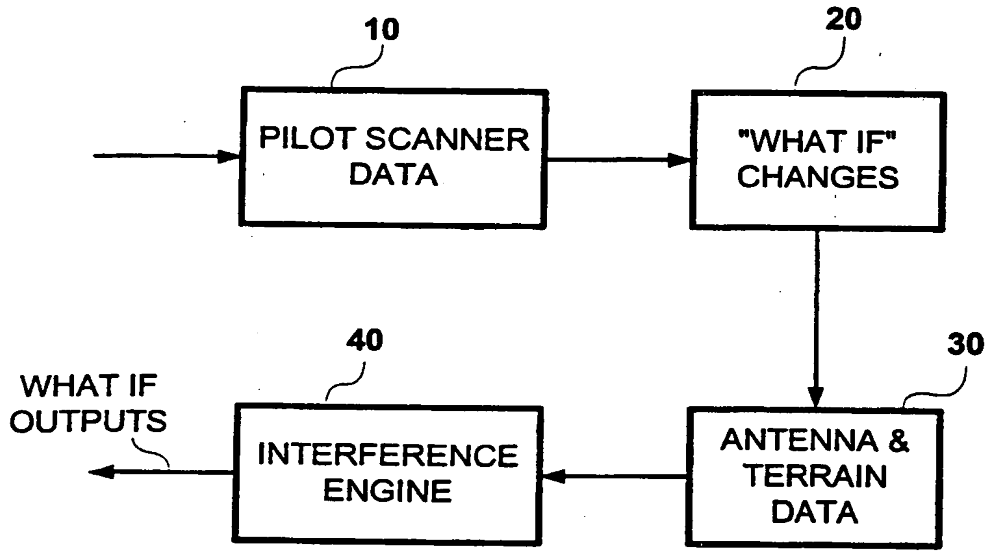
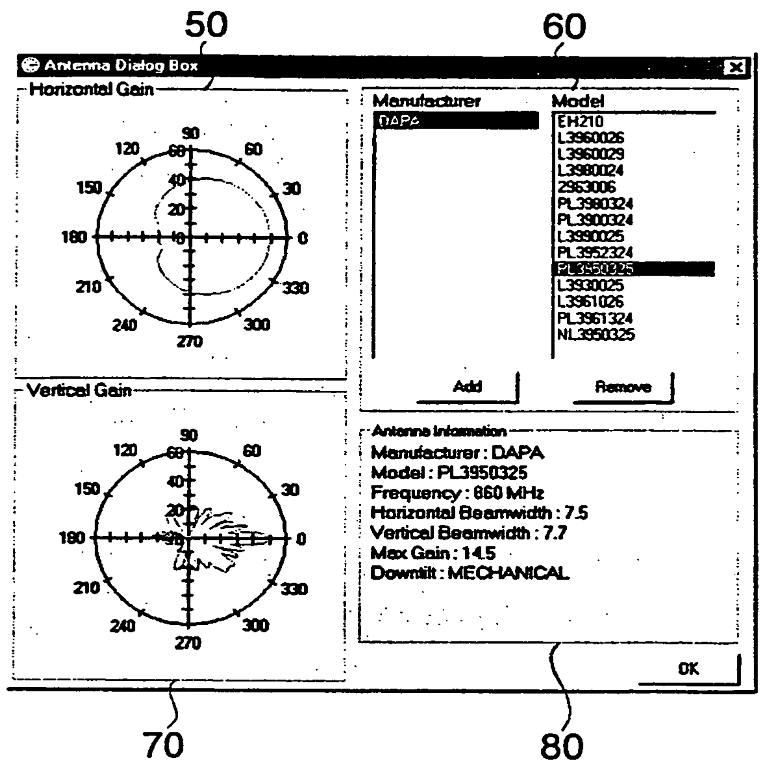

10
PILOT SCANNER DATA
20
"WHAT IF" CHANGES
30
ANTENNA & TERRAIN DATA
40
INTERFERENCE ENGINE
WHAT IF OUTPUTS

FIG. 1

FIG. 2


50
60
Antenna Dialog Box
Horizontal Gain
90
120
60
150
30
180
0
210
330
240
300
270
Vertical Gain
Manufacturer
Model
DAPA
EH210
L3960026
L3960029
L3980024
2963006
PL3980324
PL3900324
L3990025
PL3952324
PL3950325
L3930025
L3961026
PL3961324
NL3950325
Add
Remove
Antenna Information
Manufacturer : DAPA
Model : PL3950325
Frequency : 860 MHz
Horizontal Beamwidth : 7.5
Vertical Beamwidth : 7.7
Max Gain : 14.5
Downtilt : MECHANICAL
OK
70
80

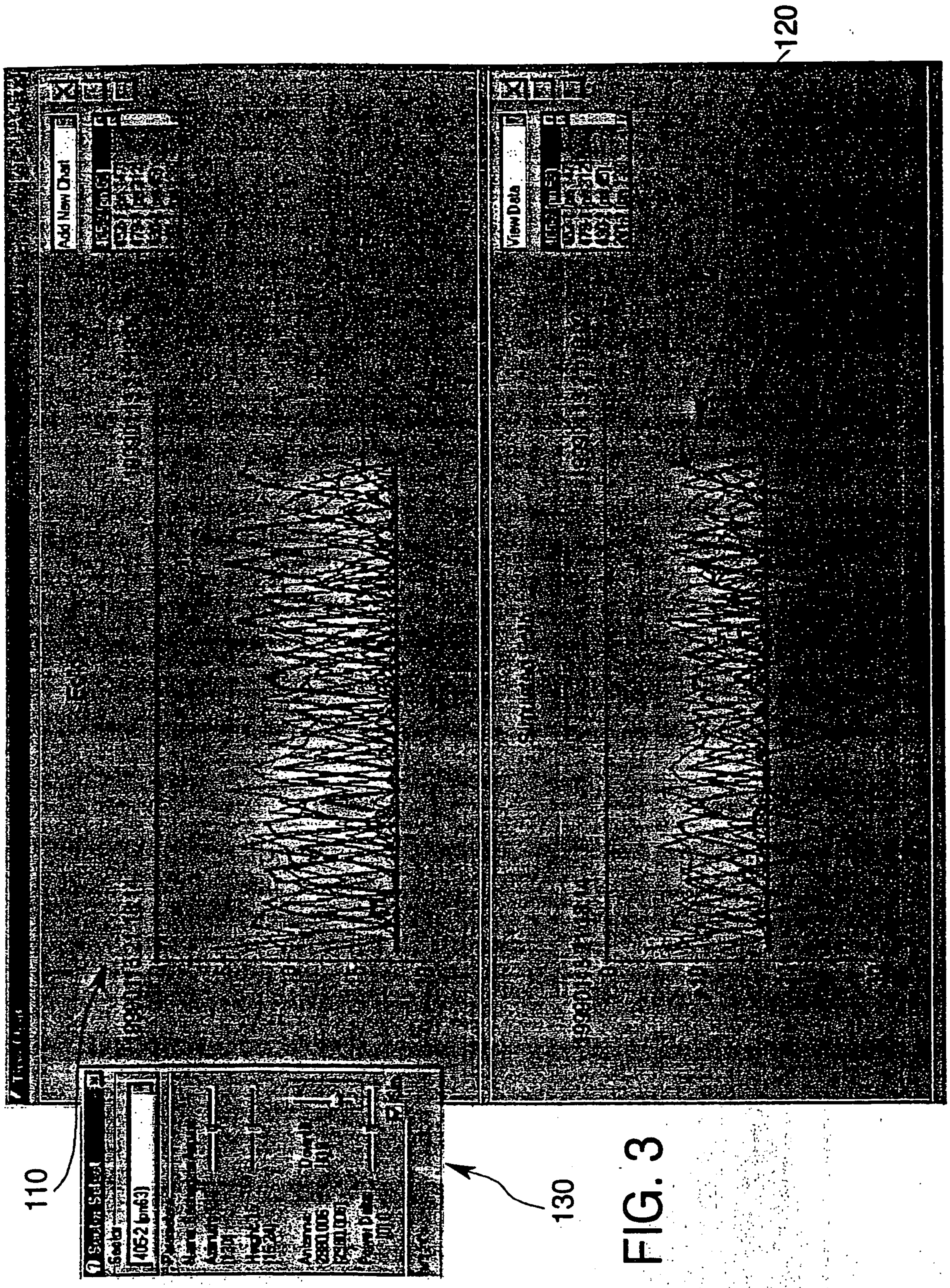

120
Add New Chart
View Data
Sector Select
Sector
4052 (pn63)
110
130

FIG. 3

FIG. 4

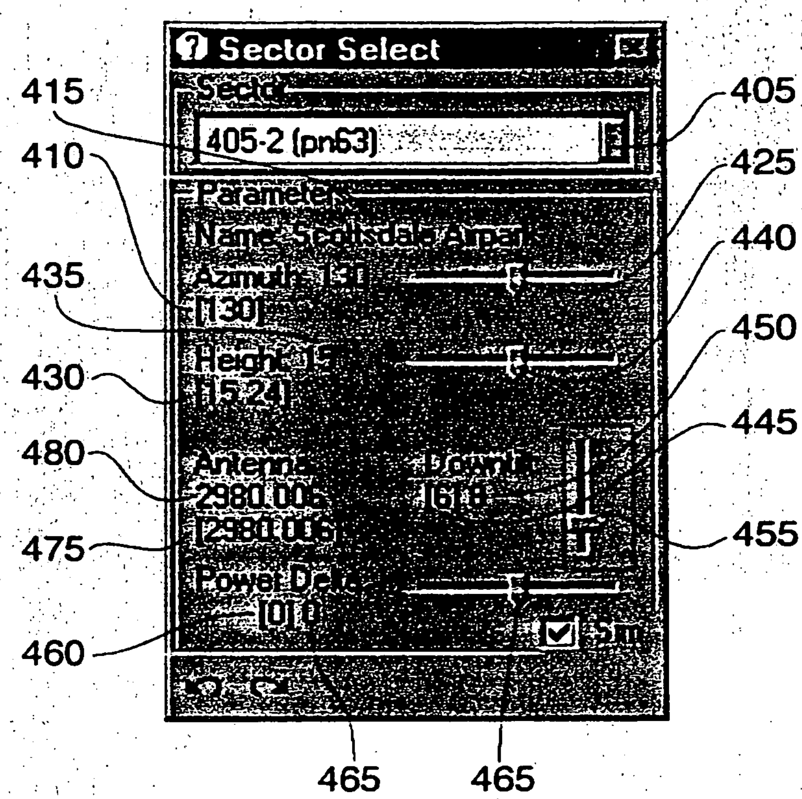

Sector Select
Sector
405-2 (pn63)
Parameters
Name: Scottsdale Airpar
Azimuth: 130
[130]
Height: 15
[15.24]
Antenna
2980.006
[2980.006]
Downtilt
[6] 8
Power Delta
[0] 0
415
410
435
430
480
475
460
405
425
440
450
445
455
465
465

FIG. 5

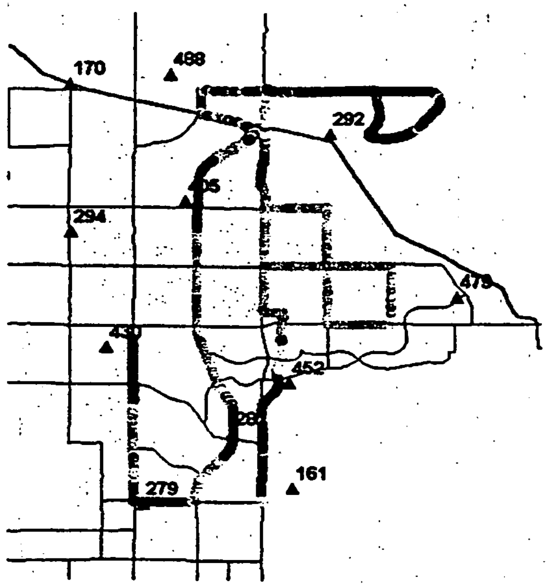
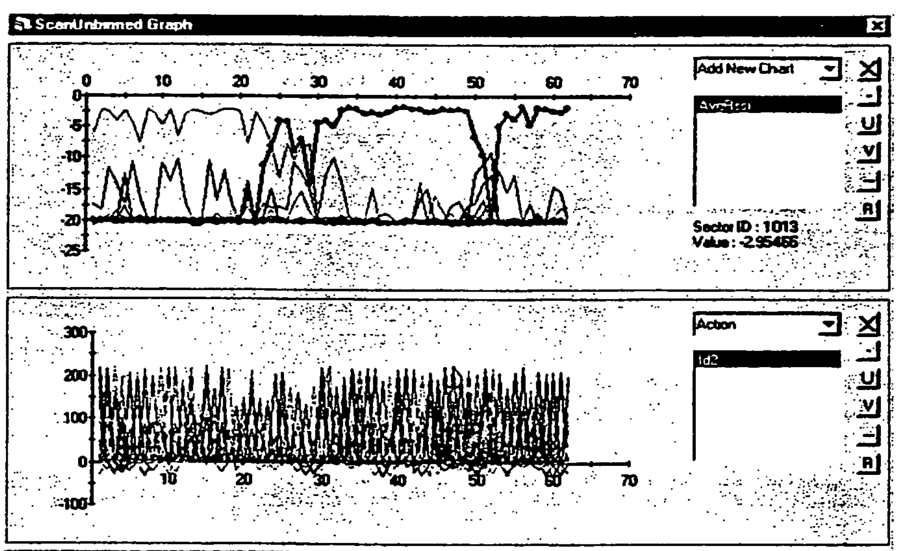

170
488
292
294
479
452
161
279

FIG. 6


ScanUnbinned Graph
Add New Chart
Sector ID : 1013
Value : -2.95456
Action
0 10 20 30 40 50 60 70
0 -5 -10 -15 -20 -25
300 200 100 0 -100

161-3 (pn 285)

	Sector Name	Weight	Number of Points	Chip Offset	SRCH_WIN_N
1	161-1 (pn 282)	65.17	174	5.8	4
2	279-1 (pn 273)	1.521	7	9.3	5
3	279-2 (pn 279)	0.666	2	8.8	5
4	281-2 (pn 144)	6.102	32	5.8	4
5	281-3 (pn 141)	6.272	23	0.9	0
6	413-1 (pn 210)	1.430	7	12.2	6
7	452-2 (pn 153)	8.626	40	11.7	6
8	452-3 (pn 150)	37.16	132	11.7	6
9	478-1 (pn 93)	0.495	3	19.1	7
10	479-3 (pn 312)	0.353	2	26.6	8

FIG. 7

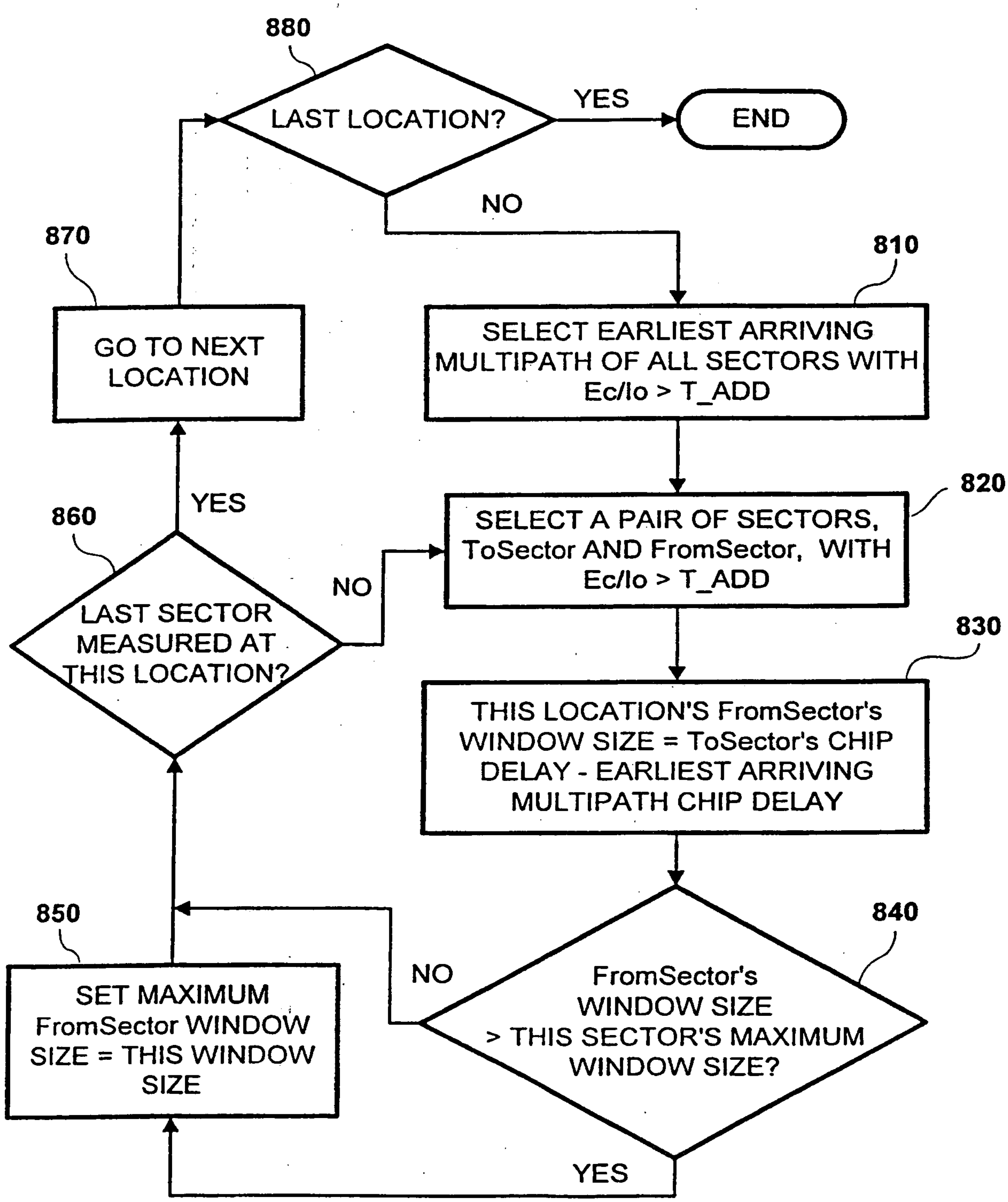

880
LAST LOCATION?
YES
END
NO
870
GO TO NEXT LOCATION
810
SELECT EARLIEST ARRIVING MULTIPATH OF ALL SECTORS WITH Ec/Io > T_ADD
820
SELECT A PAIR OF SECTORS, ToSector AND FromSector, WITH Ec/Io > T_ADD
860
YES
NO
LAST SECTOR MEASURED AT THIS LOCATION?
830
THIS LOCATION'S FromSector's WINDOW SIZE = ToSector's CHIP DELAY - EARLIEST ARRIVING MULTIPATH CHIP DELAY
850
840
NO
SET MAXIMUM FromSector WINDOW SIZE = THIS WINDOW SIZE
FromSector's WINDOW SIZE > THIS SECTOR'S MAXIMUM WINDOW SIZE?
YES

FIG. 8

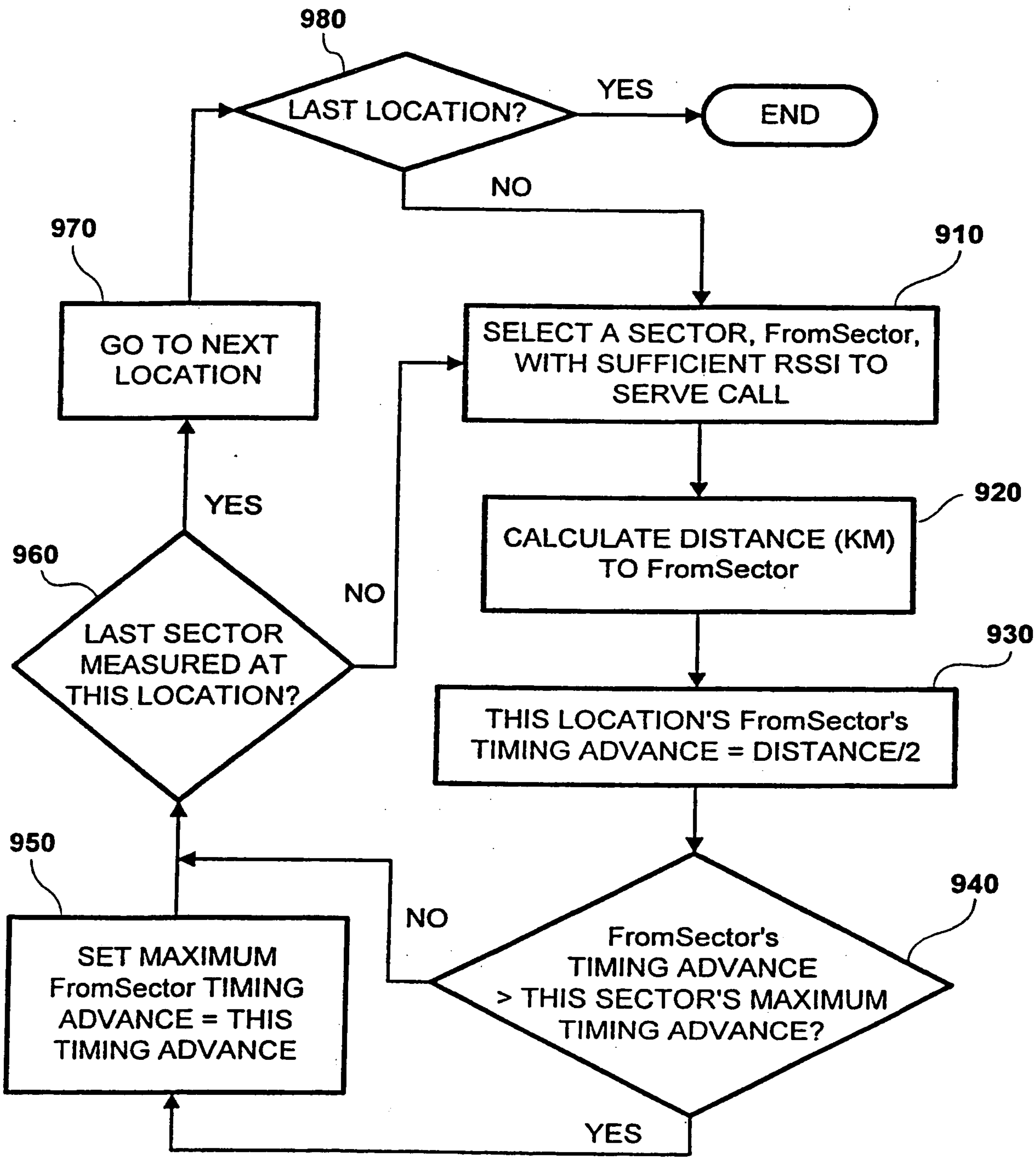

980
LAST LOCATION?
YES
END
NO
910
SELECT A SECTOR, FromSector, WITH SUFFICIENT RSSI TO SERVE CALL
920
CALCULATE DISTANCE (KM) TO FromSector
930
THIS LOCATION'S FromSector's TIMING ADVANCE = DISTANCE/2
940
FromSector's TIMING ADVANCE > THIS SECTOR'S MAXIMUM TIMING ADVANCE?
YES
NO
950
SET MAXIMUM FromSector TIMING ADVANCE = THIS TIMING ADVANCE
960
LAST SECTOR MEASURED AT THIS LOCATION?
NO
YES
970
GO TO NEXT LOCATION

FIG. 9

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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PCT

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60/149,888 19 August 1999 (19.08.1999) US

(71) Applicant: INVERTIX CORPORATION [US/US]; Suite 500, 7630 Little River Turnpike, Annandale, VA 22003 (US).

(72) Inventor: STEAD, Graham, D.; 4639 5th Street South, Arlington, VA 22204 (US).

(74) Agents: ROBERTS, Jon, L. et al.; Roberts Abokhair & Mardula, LLC, Suite 1000, 11800 Sunrise Valley Drive, Reston, VA 20191 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

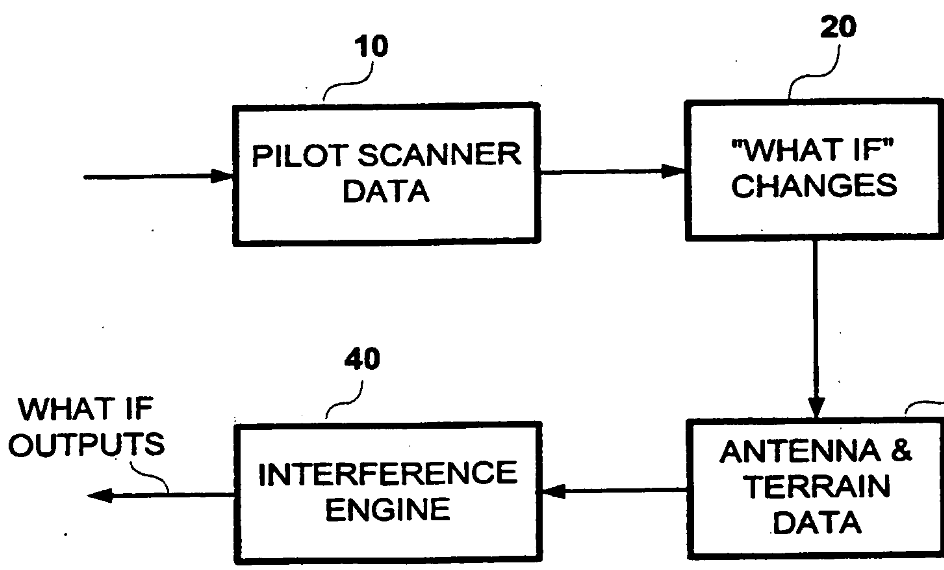
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

(88) Date of publication of the international search report: 7 June 2001

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: WIRELESS TELEPHONE NETWORK OPTIMIZATION



(57) Abstract: A wireless network can be easily optimized utilizing processes according to the present invention. A simulation environment allows a network engineer to vary parameters (e.g., antenna height, tilt, and power) of a virtual model of the wireless network and observe how the changes affect coverage. Algorithms also enable hand off timing parameters for sectors in a wireless network to be optimized. One algorithm analyzes measured data regarding network coverage and regional terrain to arrive at a report containing recommended values for window size paramaters (code division systems) or timing advance parameters (time division systems). Another algorithm analyzes measured data regarding network coverage to arrive at a report containing recommended neighbour list for each sector in the network.

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INTERNATIONAL SEARCH REPORT

In ational Application No
PCT/US 00/22873

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 40 30 825 A (TELEVERKET) 11 April 1991 (1991-04-11) column 1, line 3 - line 8 column 1, line 36 - line 46 column 2, line 8 - line 12 column 2, line 29 - line 36 column 2, line 65 - line 68; claim 2 ---	1-4
X	US 5 561 841 A (OTS MARKUS) 1 October 1996 (1996-10-01) column 2, line 21 - line 50 column 3, line 28 - line 61 column 5, line 28 - line 30 column 5, line 47 - line 50 column 5, line 64 - line 67 column 6, line 8 - line 10 column 10, line 24 - line 64 column 11, line 36 - line 52 --- -/--	1-4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 February 2001	22 FEb. 2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Leouffre, M

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/22873

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 878 328 A (VALENZUELA REINALDO A ET AL) 2 March 1999 (1999-03-02) column 1, line 56 - line 61 column 2, line 51 - line 53 column 3, line 25 - line 27 ---	1,2
A	WO 97 29557 A (TELIA AB) 14 August 1997 (1997-08-14) page 1, line 12 -page 3, line 8 page 3, line 24 -page 4, line 20 ---	2,9,13, 17
X	US 5 640 676 A (GALLAGHER TIMOTHY J ET AL) 17 June 1997 (1997-06-17)	6,11,15
A	column 2, line 57 -column 3, line 36 ---	7
X	WO 99 27718 A (MOTOROLA INC) 3 June 1999 (1999-06-03) abstract ---	6,11,15
A	WO 97 19522 A (NOKIA TELECOMMUNICATIONS OY ;STAAHLE LAURI (FI)) 29 May 1997 (1997-05-29) column 7, line 17 -column 8, line 26 ---	8,12,16
A	US 5 764 687 A (EASTON KENNETH D) 9 June 1998 (1998-06-09) column 1, line 65 - line 67 column 2, line 34 - line 45 column 3, line 58 - line 62 column 11, line 54 - line 57 column 13, line 5 - line 10 column 14, line 65 - line 68 ---	8,12,16
A	WO 97 41652 A (MOTOROLA INC) 6 November 1997 (1997-11-06) page 5, line 33 -page 6, line 8 -----	

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 00/22873

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5, 10, 14

   Simulation and graphical representation of the effect of an antenna parameter modification onto the coverage of an existing network

2. Claims: 6, 7, 11, 15

   Neighbor list determination

3. Claims: 8, 12, 16

   CDMA window size determination

4. Claims: 9, 13, 17

   Timing advance determination

INTERNATIONAL SEARCH REPORT

Information on patent family members

In. ational Application No
PCT/US 00/22873

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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			AU	715532	B	03-02-2000
			AU	7574896	A	11-06-1997
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			NO	975996	A	18-02-1998
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